Astrophysics with Gamma-Ray Polarimetry above 1 MeV
Whitepaper

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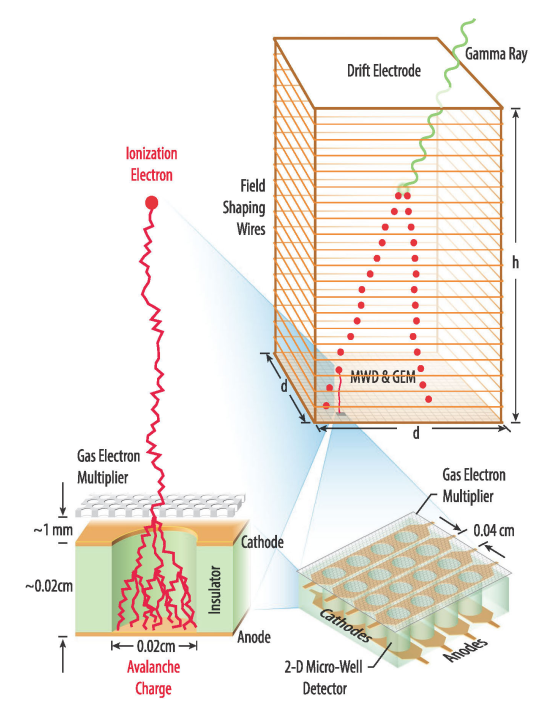
Medium-energy gamma-ray emission from a few hundred keV to several hundred MeV explores diverse astrophysical phenomenon including pulsars, supernova remnants (SNR), diffuse emission, blazars and other Active Galactic Nuclei (AGN). The key for a future mission will be to provide adequate sensitivity and the best angular resolution to go beyond simply detecting sources to making detailed spatial observations with high spectral, polarization and temporal resolution. Gamma-ray polarimetry, in particular, above 1 MeV, offers the best opportunity to address several key questions in astrophysics including 1) the origin and acceleration of cosmic rays, 2) the nature of the extreme PeV acceleration, so far identified in the Crab nebula, 3) the nature and efficiency of pulsar acceleration, and 4) the most sensitive test of vacuum birefringence from Lorentz Invariance Violation (LIV).

These questions can be addressed with a gamma-ray pair telescope technology that incorporates high spatial resolution electron tracking and a significant reduction in Coulomb scattering. By measuring the momenta of the electron-positron pair before the effects of multiple coulomb scattering dominate, it is possible to reconstruct the incident direction, energy, and polarization of individual gamma-rays with high angular resolution and significant polarization sensitivity. In addition, detection through pair production allows one to take advantage of the higher intrinsic modulation factor of polarized gamma-rays compared to Compton scattering and to image gamma-rays via electron pair production (triplet production). The Three-Dimensional Track Imager (3-DTI) technology, currently being developed for medium-energy gamma-ray telescopes (Hunter et al. 2010, 2012). The 3-DTI technology achieves the required angular resolution, polarization sensitivity and triplet detection performance by combining a large volume gas time projection chamber with negative ion drift and high spatial resolution 2-D micro-well readout to achieve high sensitivity in the medium-energy range.



Schematic of the 3-DTI technology showing how electron-positron pairs are tracked in 3-D.

A pair telescope based on 3-DTI will observe the medium-energy Universe with ~1° resolution at 70 MeV and achieve a minimum detectable polarization (MDP) of ~1% for 100 mCrab flux in the 5-200 MeV range. A telescope utilizing this technology would provide high sensitivity gamma-ray pair measurements within the next 10 years.

Hunter, S.D., et al. 2010, *Development of the Advanced Energetic Pair Telescope (AdEPT) for Medium-Energy Gamma-Ray Astronomy*, SPIE Space Telescopes and Instrumentation, 7732:773221

Hunter, S.D., et al. 2012, *Development of a telescope for medium energy gamma-ray astronomy*, Proceedings of SPIE Space Telescopes and Instrumentation vol. 8443, 84430F